OCT-20-99 WED 11:23 SPONSORED PROGRAMS-CSU FAX

AFRL-SR-BL-TR-99-

0300

29 Oct 7
1 Nov 99

REPORT DOCUMENTATION PAGE

Form Approved
OMB No. 0704-0188

1. REPORT DATE *(DD-MM-YYYY)* 10/22/99

2. REPORT DATE 10/22/99

3. DATES COVERED *(From - To)* 1/15/98--2/14/99

4. TITLE AND SUBTITLE
Bounded Derivative Initialization

5a. CONTRACT NUMBER

5b. GRANT NUMBER
F49620-98-1-0191

5c. PROGRAM ELEMENT NUMBER

6. AUTHOR(S)
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5d. PROJECT NUMBER

5e. TASK NUMBER

5f. WORK UNIT NUMBER

7. PERFORMING ORGANIZATION NAME(S) AND ADDRESS(ES)
CIRA(Cooperative Institute for Research in the Atmosphere)
NOAA/OAR/FSL
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8. PERFORMING ORGANIZATION REPORT NUMBER

9. SPONSORING/MONITORING AGENCY NAME(S) AND ADDRESS(ES)
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801 North Randolph Street, Room 732
Arlington, VA 22203-1977

10. SPONSOR/MONITOR'S ACRONYM(S)

11. SPONSORING/MONITORING AGENCY REPORT NUMBER

12. DISTRIBUTION AVAILABILITY STATEMENT
See Attached

DISTRIBUTION STATEMENT A
Approved for Public Release
~~Distribution Unlimited~~

13. SUPPLEMENTARY NOTES

14. ABSTRACT See attached

15. SUBJECT TERMS

16. SECURITY CLASSIFICATION OF: a. REPORT	b. ABSTRACT	c. THIS PAGE	17. LIMITATION OF ABSTRACT	18. NUMBER OF PAGES	19a. NAME OF RESPONSIBLE PERSON / 19b. TELEPONE NUMBER *(include area code)*
U	U	U	Unclassified		

Standard Form 298 (Rev. 8-98)
Prescribed by ANSI-Std Z39-18

20000121 003

DTIC QUALITY INSPECTED 1

Abstract

A well-posed, multiscale, fourth-order accurate, limited area model in Cartesian coordinates with a Kuo cumulus parameterization scheme was developed. The corresponding Bounded Derivative Initialization (BDI) package produced balanced initial fields from Offut AFB AVN vorticity data. The ensuing solution was essentially free of gravity waves.

AFOSR Final Report

Originally we were to be funded for three years to develop a well-posed, multiscale, fourth-order accurate, limited area model that included the Kuo cumulus parameterization scheme (with the possibility to include a cumulus parameterization scheme of the user's choosing). A Bounded Derivative Initialization (BDI) package for flows of any scale of motion and any limited area on the globe was to be included as part of the new modeling system. After the system was developed, an analysis of its sensitivity to initial, boundary, and forcing data errors was to be undertaken using mathematical theory and wavelet analyses.

Unfortunately, the funding only lasted one year because the Air Force has decided to no longer fund any meteorological research.

However, in that year we were able to develop a well-posed, muitiscale, fourth-order accurate, limited area model in Cartesian coordinates (the eventual goal was general stereographical coordinates so the model could be used anywhere on the globe) with a Kuo cumulus parameterization scheme. An integral part of this model are two test cases included as options in the code, to show the superiority of the open boundary treatment based on Kreiss well-posed and stable boundary conditions and the reduced truncation errors achievable with a true fourth-order accurate numerical method.

One of the test cases is a translating circularly symmetric storm that enters the computational domain from the southwest corner and exits through the northeast corner. The other case is balanced flow around a mountain. Both confirm the accuracy and stability of the boundary and interior numerical approximations. These test cases can be run after any modifications to the model to ensure that the dynamical core of the model has not been disturbed. They can also be run in any other model that is proposed to be numerically more accurate or stable than this model. Details of these test cases and comparison figures are available on request.

A BDI package (currently without topography) for the Cartesian model was also developed. Using real initial vorticity data interpolated from Offut AFE AVN data in the horizontal and vertical directions using Lagrangian interpolation of arbitrary order, BDI produced initial data for the remaining dependent variables. The ensuing numerical solution was essentially free of gravity waves even in the presence of Kuo heating and open boundaries. Here it should be noted that there was no dissipation of any form included in the model (such dissipation is known to reduce the numerical accuracy of other models, especially those claiming to be of higher order accuracy).

As part of this work, there was a careful review of the Kuo cumulus parameterization scheme. The scheme was found to be very sensitive to small changes in the input data. This sensitivity was tracked down and shown to be due to the unrealistic determination of the cloud base. This led to a nonphysical distribution of the heating and to nonphysical storms (which is where it was first noticed). By changing the heating distribution to a form more compatible with that discussed in the early literature, the storms became more reasonable and the initialization worked as expected.

Currently this work is being completed in collaboration with RPN (Canada). Once the basic initialization package is complete, papers describing the model and initialization package and initial real data test case (a squall line over Kansas) will be published.